Netherlands Journal of Agricultural Science 34 (1986) 441-448

Morphology, genesis, and distribution of calcareous material in Late Weichselian sediments of the Rhine and Meuse rivers in the eastern part of the Netherlands[1]

A. G. Jongmans and R. Miedema

Department of Soil Science and Geology, Agricultural University, P.O. Box 37, 6700 AA Wageningen, Netherlands

Received 5 December 1985; accepted 23 May 1986

Key words: Late Weichselian fluvial deposits, periglacial environment, fossil soil formation, decalcification, clay illuviation, biological activity, micromorphology

Abstract

In Late Weichselian sediments of the rivers Rhine and Meuse locally and haphazardly calcareous sediments were deposited. Field investigation of a cross section through a calcareous sediment, and subsequent micromorphological investigation of biological activity, decalcification and clay illuviation indicate that such local occurrences are in fact slabs of frozen, calcareous sediments, transported and redeposited as floes during periglacial conditions. Sedimentation of the calcareous material is probably of Bølling age and was accompanied by bioturbation. Decalcification, transport and resedimentation as floes occurred during the Old Dryas. Early in the Allerød the material was strongly bioturbated. Clay illuviation should be dated in the Young Dryas and gley and pseudogley formation, finally, in the Holocene.

Introduction

Late Weichselian sediments of the river Rhine in the eastern part of the Netherlands are now normally devoid of calcium carbonate, although various authors have indicated that the sediments must have contained lime originally (Bennema & Pons, 1952; Pons, 1957; Schröder, 1979). Small remnants of calcareous sediments are occasionally found in apparently random orientation patterns. Locations of such remnants are generally related to former river channels. The presently decalcified sediments feature strongly developed soils and normally have argillic B horizons (FAO, 1974), even in positions that have now impeded drainage (Miedema et al., 1978, 1983). The clay illuviation that led to the formation of the argillic horizon occurred during the Late Weichselian (Hoeksema & Edelman, 1960; Miedema et

[1] Dept. of Soil Science and Geology Publication No 871.

al., 1983). Argillic horizons of a similar age were found by Schröder (1979) in Late Weichselian to Preboreal sediments along the Rhine in West Germany, and by Langohr & Pajares (1983) and van Vliet & Langohr (1983) in Weichselian loess and other silty soils in Belgium and northern France. In Holocene sediments of the rivers Rhine and Meuse, such phenomena of clay illuviation are not encountered (van den Broek & Maarleveld, 1963; de Bakker, 1965). In a temperate climate clay illuviation does not occur in calcareous soils and therefore, the Late Weichselian sediments have lost their calcium carbonate prior to the formation of the argillic B horizon. Decalcification of sediments during the Late Weichselian was documented for loess deposits by Schröder (1979) and by Slager et al. (1978). Koenigs (1949) found pedogenic lime in Rhine sediments in the eastern part of the Netherlands that were deformed by cryoturbation after the transport of the lime. It is clear, therefore, that a strong decalcification must have preceded the Late Weichselian clay illuviation. The occurrence of calcareous bodies is therefore an anomaly for which an explanation is given in the following.

The Ven-Zelderheide section

In a section near Ven-Zelderheide in the eastern part of the Netherlands (Stiboka, 1976, Sheet 45 East/46 West East, Vierlingsbeek; coordinates 198.600 E, 412.400 N) calcareous and non calcareous Late Weichselian deposits were exposed. The section ran from a well drained plateau to a poorly drained channel. The investigated part is simplified in Fig. 1. The sediments are all of Late Weichselian age and are now well drained. In the section, five sedimentary deposits were exposed, which have been modified by soil formation.

A general description is as follows (Horizon codes according to FAO, 1977).

Sediment 5

Ap, 0-25 cm	Brown (10 YR 4/3) sand without macrostructure; clear and smooth on:
AB, 25-45 cm	Macrostructureless sand without lime; gradual and smooth on:

Sediment 4

Btg, 45-80/100 cm	Strong brown (7.5 YR 5/6) sandy loam with moderate medium subangular blocky structure; no lime; locally few iron mottles along bleached tongues, abrupt and smooth on sediment 3; clear on sediment 2.

Sediment 3

2Cgk, 80-120 cm	This horizon is discontinuous and consists of bodies of several decimeters to several meters across with a parallel, locally with an inclined orientation with respect to the soil surface. The bodies consist of light grey (7.5 YR 7/2) sandy loam that changes with depth into light grey (10 YR 7/2) sand. The material is macrostructureless and massive and contains few medi-

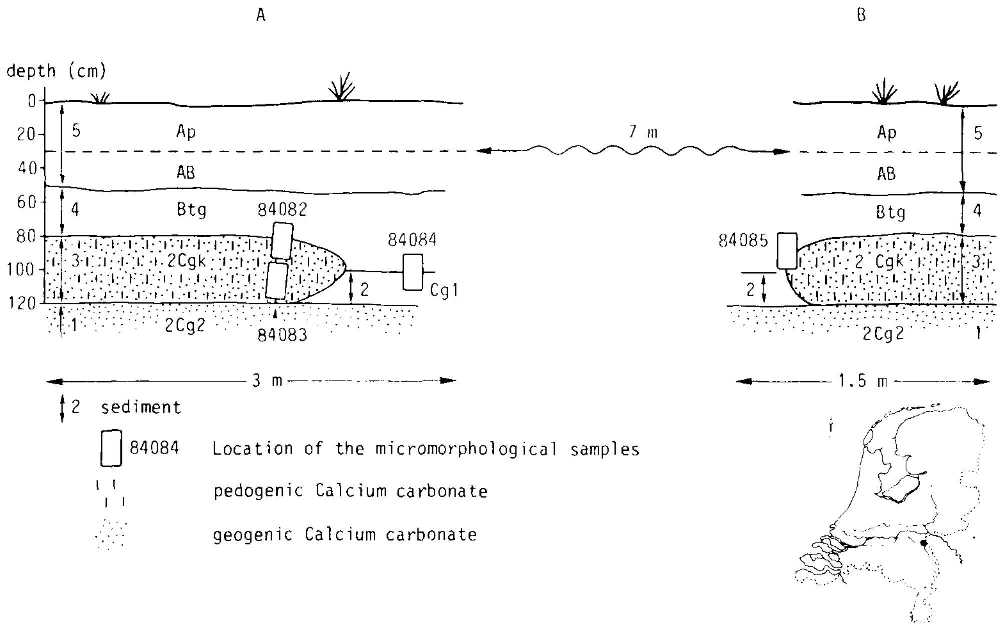

Fig. 1. Schematic cross-section in the Late Weichselian Rhine deposits in Ven-Zelderheide, Netherlands.

um and coarse iron mottles and many soft calcium carbonate accumulations. The groundmass is strongly calcareous. The sediment has an abrupt and smooth transition to sediments 2 and 1 (Fig. 2).

Sediment 2

Cgl, 100-120 cm — This intermittent horizon consists of pale brown (10 YR 6/3) sand with a single grain structure. It has few medium and coarse iron mottles and does not contain calcium carbonate; it lies abrupt and smooth on sediment 1.

Sediment 1

2Cg2, > 120 cm — This horizon consists of light grey (10 YR 7/2) sand with a single grain structure. It has common medium and coarse iron mottles. The groundmass is strongly calcareous.

Methods of investigation

Undisturbed samples for micromorphological investigation were taken at the sites indicated in Fig. 1. Mammoth-sized thin sections (8 cm × 15 cm) were prepared according to the method described by Fitzpatrick (1970). Terminology of the micro-

Fig. 2. A sandy loam body of sediments 3 showing soft calcium carbonate nodules. Detail of Fig. 1, part B.

morphological descriptions in the following paragraph is mainly according to Brewer (1964).

Micromorphological characteristics

Sediment 3; horizon 2Cgk (thin sections 84082, 84083, 84085)
The sediment contains many skeleton grains of calcite and locally the plasma has a crystic plasmic fabric. Channels, vughs and interconnected vughs are common and many ortho-matric isotubules and striotubules (1-2 mm Ø) are encountered. Neocalcitans occur in channels and vughs and may fill in or line the iso/striotubules (Fig. 3). These (neo)calcitans are 0.5 to 2 mm thick. Few iso/striotubules are devoid of calcium carbonate. The transition from sediment 3 to the adjacent sediments 4 and 1 is very sharp (within 50 μm).

Sediments 4 (horizon Btg) and 2 (horizon Cgl) (thin sections 84084, 84082, 84085)
Skeleton grains of calcite are absent. Sediment 2 has a granular fabric while that of sediment 4 is porphyroskelic. Channels, vughs and interconnected vughs are common in sediment 4 but encountered sporadically in sediment 2. Sediment 4 contains many aggro-iso/striotubules of 1-3 mm Ø, which are mainly devoid of calcite. Some tubules contain calcite from sediment 3. Sediment 4 contains many channel and normal-void ferriargillans with a continuous orientation and a random distribution pattern. In aggrotubules, however, the ferriargillans have a clustered dis-

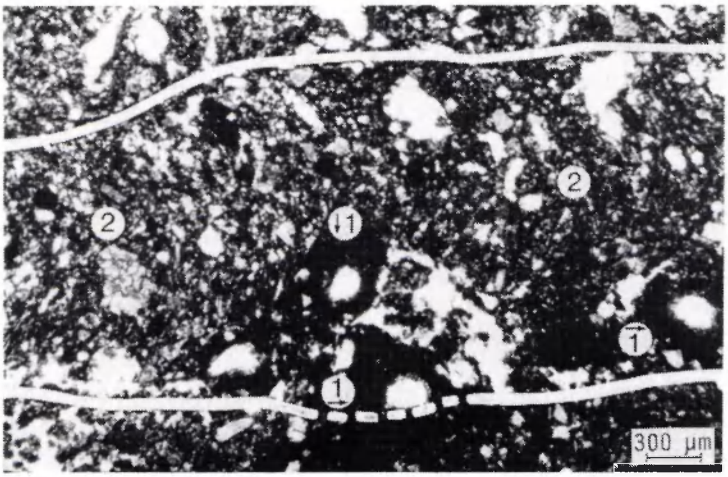

Fig. 3. Channel neocalcitan (1) occurring in an ortho iso/striotubule (2). Transmitted light.

tribution pattern. Ferriargillans are also found in shrinkage fissures between iso/striotubules and the surrounding material. In the brownish parts of the Bt horizon, ferriargillans are impregnated with very fine (smaller than 10 μm) iron hydroxide droplets. In the greyish tongues, the ferriargillans have lost much of their iron and have become argillans. Their orientation has become discontinuous and they have a grainy appearance. In the greyish parts, nodules of iron and manganese partly cover pedotubules and argillans. The large number of calcite skeleton grains in sediments 1 and 3 indicates that these were calcareous deposits. Channel and normal-void neocalcitans in sediment 3 are the result of decalcification and redistribution. The fact that such neocalcitans are not encountered in the adjacent sediments 2 and 4 suggests that decalcification in 3 occurred before sediment 4 was deposited. Iso/striotubules in sediment 3 are filled in or lined by neocalcitans, which indicates that biological activity preceded migration of calcite. Also the ferriargillans are formed posterior to the biological activity, because ferriargillans are encountered in interconnected vughs in shrinkage cracks along tubules. However, since the ferriargillans are found in sediment 4, which was deposited after sediment 3, biological activity in sediment 4 should be of a later date than that in sediment 3. Pseudogley, as witnessed by grey tongues and iron-manganese segregation, superseded clay illuviation; ferriargillans are depleted of iron or partly covered with segregation products (Miedema et al., 1978, 1983). The disappearance of continuous orientation in the argillans and the grainy appearance of the latter indicates breakdown of clay by ferrolysis (Brinkman et al., 1973), a process associated with pseudogley.

Discussion

The upper part of the Late Weichselian fluvial sediments in the Netherlands represents the terminal stage of a braided river system (Schelling, 1951; Miedema et al., 1978). This terminal stage is normally recognized in a fining upwards sequence with a gradual transition of sandy to clayey sediments. In the present cross section, boundaries between sediment 3 and the surrounding sediments are very abrupt and suggest that periglacial processes may have played a role. In a permafrost landscape such as occurred during the Late Weichselian, meltwater flowing through channels will melt the permafrost in the banks at the water level. When part of the ice is molten, undermining of the river bank results in breaking-off of still frozen topsoil material, which will float on the water as a floe of frozen sediment and may be deposited downstream without losing its structure (French, 1976). Such phenomena were described by Dylik (1969) from periglacial environments of Poland and floes were observed elsewhere in Late Weichselian deposits of the river Meuse by the present authors.

The transport of frozen slabs of calcareous material as floes explains both the abrupt transitions between the calcareous slabs and the surrounding sediments and the haphazard occurrence of such slabs in or next to former channels. Because the processes of decalcification, bioturbation, clay illuviation and floe transport are all restricted to the Late Weichselian, it is necessary to draw conclusions as to the sequence of these processes and their relation to cold or warmer stages. A reconsideration of sedimentation history and micromorphological observations leads to the following sequence of processes.

- Sediments 1 (sand) and 3 (sandy loam) were deposited during the Late Weichselian and were strongly calcareous. Decalcification of sediment started shortly after deposition and is prior to the transport of floes of this sediment during periglacial conditions. This is suggested by the fact that neocalcitans are restricted to sediment 3. Because in sediment 3 the tubules caused by biological activity are partly covered by neocalcitans, bioturbation preceded decalcification and it is likely that the calcareous sediments have been strongly bioturbated during deposition.
- Floes of sediment 3 were transported and redeposited before decalcification of the landscape was completed because they still contain primary $CaCO_3$. After redeposition the slabs acted as isolated bodies that were preserved below the groundwater level or that were not affected by percolation because vertical water movement went around them.
- After deposition of the floes, sediments 2, 4 and 5 were deposited. The presence of clay cutans in interconnected vughs in and in shrinkage cracks along aggrotubules indicates that also these sediments were strongly bioturbated during deposition and that clay illuviation postdates bioturbation.

If sediment 3, in its original position was deposited during the Bølling stage of the Late Weichselian, the biological activity that mixed the calcareous sediments may have continued to the Old Dryas stage. Remains of Allerød time volcanic activity (Frechen, 1959; Frechen & Heide, 1969) were not encountered in sediment 3. Therefore, this sediment must be older than Allerød. Its medium textured character points to sedimentation in a warm period, presumably the Bølling stage. Biological activity during the Bølling period was also found in the South Limburg loess by Slager et al. (1978). Strong decalcification is probably connected with the cold Old Dryas stage. Similar conclusions were reached for decalcification of the pre-Allerød Lower Terrace in West Germany by Schröder (1979). The transport of slabs of sediment 3 as floes is probably also of Old Dryas age. The absolute absence of calcite in sediments 2, 4 and 5 suggests that these have never contained considerable amounts of calcite or that synsedimentary decalcification is responsible for this feature. Because also these sediments 2, 4 and 5 are devoid of volcanic admixtures, their sedimentation should be completed before the Allerød volcanic eruptions. The biological activity probably continued through the Allerød, while the main phase of clay illuviation occurred during the Young Dryas and possibly the Early Preboreal. The (pseudo)gley formation and related ferrolysis is undoubtedly of Holocene age and is due to an increase in precipitation and to a rise of the groundwater level parallel to the rise of the sealevel during the Holocene. Present biological activity is responsible for the occurrence of non calcareous pedotubules in sediment 3 and calcareous pedotubules in sediment 4.

Acknowledgements

The authors wish to thank Dr P. Buurman for his critical review of an earlier draft of this paper and the stimulating discussions on the subject.

References

Bakker, H. de, 1965. Tonverlagerung in Flussablagerungen verschiedener Art. *Mitteilungen der Deutschen Bodenkundlichen Gesellschaft* 4: 123-128.

Bennema, J. & L. J. Pons, 1952. Donken, Fluviatiel Laagterras en Eemzee-afzettingen in het westelijk gebied van de grote rivieren. *Boor en Spade* V: 126-137.

Brewer, R., 1964. Fabric and mineral analysis of soils. Wiley, New York, 470 pp.

Brinkman, R., A. G. Jongmans, R. Miedema & P. Maaskant. 1973. Clay decomposition in seasonally wet acid soils: Micromorphological, chemical and mineralogical evidence from individual argillans. *Geoderma* 10: 259-270.

Broek, J. M. M. van den & C. G. Maarleveld, 1963. The Late Pleistocene terrace deposits of the Meuse. *Mededelingen van de Geologische Stichting, Nieuwe Serie* 16: 13-25.

Dylik, J., 1969. Slope development under periglacial conditions in the Lodz region. *Biuletyn Peryglacjalny* 18: 381-410.

FAO-UNESCO, 1974. Soil Map of the World 1:50.000, Vol. I: Legend. FAO-UNESCO, Paris, 59 pp.

FAO, 1977. Guidelines for soil profile description, 2nd ed. FAO, Rome, 66 pp.

Fitzpatrick, E. A., 1970. A technique for the preparation of large thin sections of soils and unconsolidated materials. In: D. A. Osmond & P. Bullock (Eds.), Micromorphological techniques and applications. Technical Monograph no 2, Agricultural Research Council, Soil Survey of England and Wales, Rothamsted Experimental Station, Harpenden, Herts: 3-13.

Frechen, J., 1959. Die Tuffe des Laacher Vulkangebietes als quartärgeologische Leitgesteine und Zeitmarken. *Fortschritte Geologie Rheinland und Westfalen* 4: 363-370.

Frechen, J. & G. Heide, 1969. Tephrastratigraphische Zusammenhänge zwischen der Vulkantätigkeit im Laacher Seengebiet und der Mineralführung der Terrassenschotter am unteren Mittelrhein. *Decheniana* 122: 35-74.

French, H. M., 1976. The Periglacial Environment. Longman, London and New York, 307 pp.

Hoeksema, K. J. & C. H. Edelman, 1960. The role of the biological homogenisation in the formation and transformation of gray-brown podzolic soils. Transactions 7th International Congress of the International Soil Science Society, Madison, Vol. 4: 402-405.

Koenigs, F. F. R., 1949. De bodemkartering van Nederland. Deel III; Een bodemkartering van de omgeving van Azewijn. *Verslagen Landbouwkundige Onderzoekingen* No 54.14. 's-Gravenhage, 43 pp.

Langohr, R. & G. Pajares, 1983. The chronosequence of pedogenic processes in fraglossudalfs of the Belgium loess belt. In: P. Bullock & C. P. Murphy (Eds.), Soil micromorphology, Vol. 2: Soil genesis, p. 503-511. A.B. Academic Publishers, Berkhamsted, U.K.

Miedema, R., E. van Engelen & Th. Pape, 1978. Micromorphology of a toposequence of Late Pleistocene fluviatile soils in the Eastern part of the Netherlands. In: M. Delgado (Ed.), Micromorfologia de Suelos, Vol. I, p. 469-501. T. Arte Prieto Moreno, Maracena (Granada), Spain.

Miedema, R., S. Slager, A. G. Jongmans & Th. Pape, 1983. Amount, characteristics and significance of clay illuviation features in Late Weichselian Meuse deposits. In: P. Bullock & C. P. Murphy (Eds.), Soil micromorphology, Vol. 2: Soil genesis, p. 519-529. A.B. Academic Publishers, Berkhamsted, U.K.

Pons, L. J., 1957. De geologie, de bodemvorming en de waterstaatkundige ontwikkeling van het Land van Maas en Waal en een gedeelte van het Rijk van Nijmegen. Bodemkundige studies No 3, Stiboka, Wageningen, 156 pp.

Schelling, J., 1951. Een bodemkartering van Noord-Limburg. *Verslagen Landbouwkundige Onderzoekingen* No 57.17. 's-Gravenhage, 139 pp.

Schröder, D., 1979. Bodenentwicklung in Spätpleistozänen and Holozänen Hochflutlehmen des Niederrheines. Habilitationsschrift, Bonn, 296 pp.

Stiboka, 1976. Bodemkaart van Nederland, Blad 45 Oost ('s-Hertogenbosch), Blad 46 West-46 Oost (Vierlingsbeek). Pudoc, Wageningen, 209 pp.

Slager, S., A. G. Jongmans, R. Miedema & L. J. Pons, 1978. Fossil and recent soil formation in Late Pleistocene loess deposits in the southern part of the Netherlands. *Netherlands Journal of Agricultural Science* 25: 326-335.

Vliet, B., van & R. Langohr, 1983. Evidence of disturbance by frost of pore ferriargillans in silty soils of Belgium and Northern France. In: P. Bullock & C. P. Murphy (Eds.), Soil micromorphology, Vol. 2: Soil genesis, p. 511-518. A.B. Academic Publishers, Berkhamsted, U.K.